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# *Effects of Roughness and Honing Angle on Tribological Properties of Cylinder Liner*

**Xiaoguang Tian, Lina Liu, Feiyue Qin**

*Huanghe Jiaotong University, Jiaozuo, Henan, 454000, China*

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***Abstract:*** The tribological properties of cunicr cylinder liner with different honing morphology and crgal2o3 coated piston ring were studied. The wear surface morphology and element distribution of cunicr cylinder liner, as well as the effects of honing angle and roughness on cylinder liner friction and wear and tensile cylinder performance were analyzed. The results show that, Optimizing honing angle and roughness can effectively improve the tribological performance of cylinder liner. Honing angle and roughness not only affect the wear mechanism between piston ring and cylinder liner, but also have a great impact on the distribution and maintenance of lubricating oil film, and then affect its friction and wear and tensile cylinder performance

## 1. Introduction

As an internal combustion engine widely used in today's society, the performance of diesel engine directly determines the mechanical efficiency and reliability of the whole power system. With the improvement of its power density, the cylinder liner and piston ring as key friction pairs will bear more thermal and mechanical loads than ever before, In order to improve the tribological properties of cylinder liner and piston ring friction pair, changing the inner surface morphology of cylinder liner is a common method in internal combustion engine industry

## 2. Development of Cylinder Liner Tribology

In the past, it was generally believed that the smooth inner wall of the cylinder liner was conducive to reducing the direct contact of the surface micro convex body, so as to reduce the friction. However, this mirror like surface structure could not store lubricating oil during the working process, and the actual contact area of the surface was large during the contact between the cylinder liner and the piston ring. With the aggravation of the working conditions, The tribological performance of cylinder liner and piston ring system will gradually deteriorate. Therefore, surface texture is widely used as a preferred cylinder liner surface processing method in the industry. Platform honing, as a surface texture, is one of the most stable and widely used surface processing methods at present[1]. Compared with cylinder liner without surface honing, Surface honing can significantly reduce the friction loss and lubricating oil consumption of the friction pair. It can produce a large bearing platform on the inner wall of the cylinder liner, and at the same time, many honing lines for storing lubricating oil can be formed between the bearing platforms. When the diesel engine is working, these special structures play an important role in lubricating oil storage and lubricating oil film formation[2]. In addition, G. Through the test, S. Joshi found that the rough honing surface is easier to form lubricating oil film, and there is an obvious relationship between lubricating oil film thickness and roughness. S. Yuan found that the friction and wear performance of cylinder liner is related to the distribution direction of honing reticulation on its surface. While the honing angle and roughness affect the friction and wear performance of cylinder liner under the condition of high power density, In particular, there are few reports on the influence of tensile cylinder performance.

The friction pair material itself must be considered in the study of the tribological properties of the cylinder liner friction pair. Eunseokkim explored the influence of honing surface roughness on the friction and wear properties of the cylinder liner, but the honing material used in the test is ordinary steel ball rather than real piston ring. Although the above research results have certain reference significance for exploring the influence of honing morphology on the friction and wear properties of the cylinder liner[3], However, the test results on real cylinder liner and piston ring samples are more reliable, The effects of honing angle and roughness on the wear and tensile cylinder performance of cunicr cylinder liner are investigated. Under the working conditions of high combustion pressure and high temperature, the influence laws and related action mechanisms of cunicr cylinder liner with different honing angle / roughness are compared.

## 3. Effect of Honing Angle on Friction and Wear Properties of Cylinder Liner

### 3.1 Effect of on Cylinder Liner Wear and Friction Coefficient

Honing angle has a significant effect on the friction and wear performance of cylinder liner; With the increase of honing angle (47 ° ~ 65 °), the wear amount and friction coefficient of friction pair first decrease and then increase.

### 3.2 Mechanism of Influence on Tribological Properties of Cylinder Liner

With the decrease of honing angle (from 65 ° to 58 °), the distribution direction of honing pattern gradually tends to be perpendicular to the sliding direction. The greater the included angle between honing pattern distribution direction and sliding direction, the greater the blocking effect on lubricating oil flow in the relative sliding process of friction pair, Thus, a local lubricating oil vortex is formed in the honing grain. This lubricating oil vortex can show a better bearing capacity between the two contact surfaces, so as to improve the tribological performance of the friction pair. However, when the honing angle is reduced more (from 58 ° to 47 °), the actual contact area between the cylinder liner piston rings will increase, This may aggravate the wear between the friction pairs[4]. Tomanik obtained the same law as the above friction and wear test by establishing the statistical roughness contact model, which also proved that changing the honing angle can change the tribological performance of the cylinder liner. The wear test results show that the honing angle of cunicr cylinder liner is about 58 °.

## 4. Effect of Honing Surface Roughness on Friction and Wear Properties of Cylinder Liner

### 4.1 Effect on Friction Coefficient

With honing, the surface roughness increases from 0.7 μ M increased to 0.85 μ m. However, as the honing surface roughness continues to increase (from 0.85 μ M to 0.98 μ m) When the honing surface roughness increases to 1.25 μ M, the friction coefficient reaches a relatively stable state. It can be seen that the honing surface roughness is 0.85 μ M, cunicr cylinder liner has the lowest friction coefficient.

### 4.2 Effect on Wear of Cylinder Liner and Piston ring

With the increase of honing surface roughness of cylinder liner, the wear of cylinder liner and piston ring decreases first and then increases. The honing surface roughness is 0.85 μ When m, the comprehensive wear is the smallest. It can be seen that the best honing surface roughness of cunicr cylinder liner should be 0.85 μ M or so.

### 4.3 Running in Period Time of Entering Stable Wear Stage

Honing surface roughness minimum (0.7 μ m) The time for the friction pair to enter the stable high load running in is the shortest, about 1.3h, while the honing surface roughness is high (0.98 μ M and 1.25 μ m) It can be seen that with the increase of honing surface roughness, the time to enter the stable high load running in stage gradually increases, which means that honing surface roughness also affects the running in performance of cylinder liner under high load conditions.

To sum up, the cylinder liner with lower honing surface roughness has relatively poor tribological performance, but the time to enter the stable wear period is also short. This phenomenon is because the height difference between honing peak and honing Valley on the cylinder liner surface with higher honing surface roughness is relatively large, and the meshing force required to smooth the micro convex body on the honing surface is large in the grinding process, It also takes a long time to flatten the rough surface.

### 4.4 Surface Morphology and Element Distribution At the Dead Center of Cylinder Liner after Wear Test

After wear, the surface morphology of each cylinder liner sample is basically the same, and the composition of surface elements is also the same except for different mass fractions. After wear, the surface honing texture is still clear, a small part of the texture has been flattened, and some abrasive fragments have been rolled into the honing texture. In addition to the matrix elements of cylinder liner, the wear area also contains lubricating additive element P, S and ca. lubricating oil additive elements can be observed on cylinder liner samples with different honing roughness, and the honing surface roughness is 0.7 μ The surface of M contains the least lubricating oil elements (P, s and CA), while the honing surface roughness is 1.25 μ M cylinder liner sample contains more lubricating oil additive elements. The increase of lubricating oil element mass fraction means that the quality of lubricating oil stored on the working surface increases. This phenomenon is due to the different honing pattern depths of cylinder liners with different honing surface roughness. Cylinder liners with larger honing surface roughness have deeper honing patterns. Therefore, their ability to store lubricating oil is relatively strong, and there are more lubricating oil elements on the surface after wear test.

### 4.5 Wear Mechanism of Cylinder Liner with Different Honing Surface Roughness

The wear resistance of the friction pair depends on its own characteristics and working conditions. In this test, the working conditions of each friction pair are consistent, so the changes of the friction coefficient and wear amount of the friction pair are caused by the different surface roughness of the inner wall of the cylinder liner. It can be seen from the wear test results that with the increase of the honing surface roughness of the cylinder liner, The friction performance has not been continuously improved. For cylinder liner samples with small honing surface roughness (0.7 μ M and 0.85 μ m) , the honing pattern on the worn surface is clear and smooth, and there is no obvious material peeling and plastic deformation on the worn surface. For the cylinder liner sample with large honing surface roughness (0.98 μ M and 1.25 μ m) , obvious plastic deformation and fatigue spalling were found on the worn surface, and the honing pattern was gradually filled by the plastic flow layer and disappeared μ M increased to 1.25 μ M, the wear depth of the friction pair increases. This is because the height difference between the honing peak and honing Valley on the inner surface of the cylinder liner with larger roughness is larger. Compared with the cylinder liner with smaller honing roughness, the cylinder liner with larger roughness is more prone to substrate adhesion, tear, drag and peeling in the process of contacting with the piston ring.

Under the condition of high combustion pressure and high temperature gradient, the material on the surface of the honing platform is prone to plastic deformation and extrusion along the parallel or vertical sliding direction[5]. The thin layer generated by plastic flow on the cylinder liner surface with large honing roughness will gradually form at the edge of the bearing platform. Due to the reciprocating sliding between the contact surfaces, More plastic flow thin layers are rolled into the honing grain and gradually filled, eventually increasing the actual contact area between the cylinder liner and the piston ring. In addition, the thin layer will also break and peel off at the edge of the honing platform during rolling, and finally form abrasive particles between the sliding surfaces. These abrasive particles will increase the mechanical bite force between the two contact surfaces and cause serious abrasive wear, Finally, its friction and wear properties are reduced.

### 4.6 Effect of Honing Surface Roughness on Tensile Performance of Cylinder Liner

With the increase of honing surface roughness, the anti tension cylinder time first increases and then decreases. The honing surface roughness is 0.85 μ The cylinder liner of M has the longest anti pull cylinder time, indicating that the cylinder liner has good anti pull cylinder performance. This phenomenon may be caused by the following two reasons: a) the honing pattern itself has a certain oil storage performance, which can provide lubricating oil after oil cut-off; The honing surface with larger roughness has deeper honing lines, so it takes more time to deplete the lubricating oil stored on its surface; b) The surface with larger roughness will produce more abrasive particles, which will cause certain abrasive wear between the two surfaces after oil cut. In addition, the abrasive particles will be squeezed into the honing grain, so as to squeeze out the lubricating oil stored in the honing grain, which will accelerate the consumption of lubricating oil and shorten the time of anti tension cylinder. Similar phenomena have been reported before, Zabala pointed out that proper honing pattern depth can greatly increase the thickness of surface lubricating oil film, while deeper honing pattern will cause local lubricating oil film collapse, and eventually lead to lubricating oil film thinning or even rupture.

## 5. Conclusion

The honing angle has a significant effect on the friction coefficient and wear. When the honing surface roughness remains unchanged, the honing angle of about 58 ° shows better tribological properties; Cylinder liner wear mechanism: the material on the surface of the honing platform deforms plastically under the action of normal load. At the same time, the plastic flow thin layer is extruded from the edge of the contact platform, and finally cracks and falls off in the defect or stress concentration area to form debris; With the increase of honing surface roughness of cylinder liner, the friction coefficient and wear amount first decrease and then increase. The test results show that the surface roughness of cunicr cylinder liner is 0.85 μ M has the lowest wear and the best tensile cylinder performance.

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